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SOIL SAMPLING FOR PORE SPACE AND PERCOLATION

Field and Laboratory Procedures

by

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Evaluation of the physical properties of soil as found in place has become increasingly important to an understanding of watershed characteristics and suitability of sites for tree growth. In studies concerned with the properties of Piedmont soil conditions, the Piedmont Research Center has for several years been collecting soil cores to measure pore space and percolation rates. This report summarizes the methods and describes the equipment which has been developed.

FIELD METHODS

Two methods of obtaining undisturbed[1/] soil cores for the study of the properties of natural field soils have been used at the Piedmont Research Center. In one method an enlarged version of a sampler designed by J. F. Lutz (3) is used. This method will be referred to as the pit method, as samples are collected by digging a pit. The second method, which will be referred to as the machine method, uses the Utah Soil Sampling Machine (1) and no pit is needed for sample collection.

Satisfactory samples cannot be easily collected from extremely rocky soils or where there are numerous large roots. The pit method is usually easier to use than the machine where there are many large rocks in the surface layers, because it gives an opportunity to select portions of the pit face where rocks are least abundant. The machine method is best where large roots are present. Although the portion of the core collected with the machine will be unsatisfactory where a root is cut, it is easy to move over and take another sample. Only rarely will roots be struck at the same depth and thus from several cores a sufficient number of samples can be obtained to represent all soil depths to be studied.

In choosing the time to sample, soil moisture is the important consideration. The right time to get good samples is when the soil is at field capacity or slightly below. At this moisture content, structural cracks and

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1/ Undisturbed is used advisedly and what is actually meant is soil samples taken with little disturbance to natural structure.

cleavages are almost closed and there is sufficient moisture present to lubricate the sample, so that it enters the collecting device with minimum disturbance. When the soil is above field capacity, it may have a tendency to flow and is compacted by the sampling. A soil too dry does not hold together and is difficult to sample. Pit digging is also a formidable job in dry soil.

It is believed that bulk density determinations should be made when the soil is near field capacity. At this time, cracks and cleavage planes are closed. When the soil dries, it shrinks and cracks open. While the density of an aggregate may increase as it dries, that of a soil horizon remains the same because of the increase in the volume of large voids. None of the methods of collecting soil allows representative sampling of the large openings, and at low moisture content bulk density values are obtained which do not truly represent the soil horizon. Samples for bulk density determination taken near field capacity need not be corrected for moisture content and give the best measure of total soil pore space.

Another reason for sampling when moisture content is near field capacity is that percolation rates and pore space measurements are to be run on the samples when they are saturated. Samples taken when field moisture is low require a long soaking period to saturate and may swell excessively. It is best to take samples when they are naturally expanded by wetting in the field.

In some soils and some situations it may be practical to wet soils artificially to the proper moisture content. In Piedmont soils with heavy sub-soil horizons, this cannot be easily done. However, some success has been attained by digging holes with a post-hole auger to depths of 3 feet or so and keeping these holes flooded with water for a few days. Artificial wetting is generally feasible only when a few localities are to be sampled; as a rule it is not practical. The most satisfactory time for soil sampling in the Piedmont is during late winter and early spring, when the soil is naturally wet to field capacity.

Pit Sampling

The procedure for pit sampling is essentially the same whatever device is used to collect the soil samples themselves. First, the soil pit must be dug. Samples should be collected the same day the pit is dug, before the exposed soil face dries or the pit becomes filled with rain water. For sampling depths of 3 feet or more, the pit should be at least 5 feet long or it will not be possible to throw out the dirt. A 3-foot width of face is the practical minimum for satisfactory sampling. The tools ordinarily required to dig the pit are a mattock, long-handled round-point shovel, and a spade. To aid in backfilling the pit and to keep the site free of loose scattered soil after sampling is completed, it is helpful to place excavated soil on a canvas tarpaulin.

The sampler used at the Piedmont Research Center is shown in figures 1 and 2. This sampler holds a copper cylinder in which the soil is collected. It is driven by impact using the 12 to 16 pound hammer illustrated in the figures. Because the hammer is mounted on a rod which slides inside the sampler handle, the sampler can be driven with a minimum of wobble. Generally, when sampling heavy soils one man guides the sampler while another man uses

the hammer. A heavy hammer avoids some of the jarring and breakdown of structure caused by many blows from a lightweight hammer.

The copper cylinders in which soil is contained are cut from 3-inch copper pipe. The inside diameter is 7.60 cm. and the cylinders are cut to be 5.51 cm. long to hold 250 ml. Cylinders are fitted with lids made from sheet copper. The top lid and cylinder are numbered and stay together throughout the field and laboratory procedure. Lower lids are interchangeable and used only until the sample begins laboratory processing. A small hole is drilled into the top lid to prevent air trapping during saturation and to allow entry of air when the sample is on the tension table.

The copper cylinder is slipped into the sampler after removing the sampler cutting head, which is held only by a loose friction fit. The cutting head is not tempered or specially hardened and is easily kept in shape with a carborundum stone and file. The most satisfactory cutting surface is square edged and about 1/32 inch wide. A knife-like cutting edge does not cut roots as well and is quickly damaged by rock.

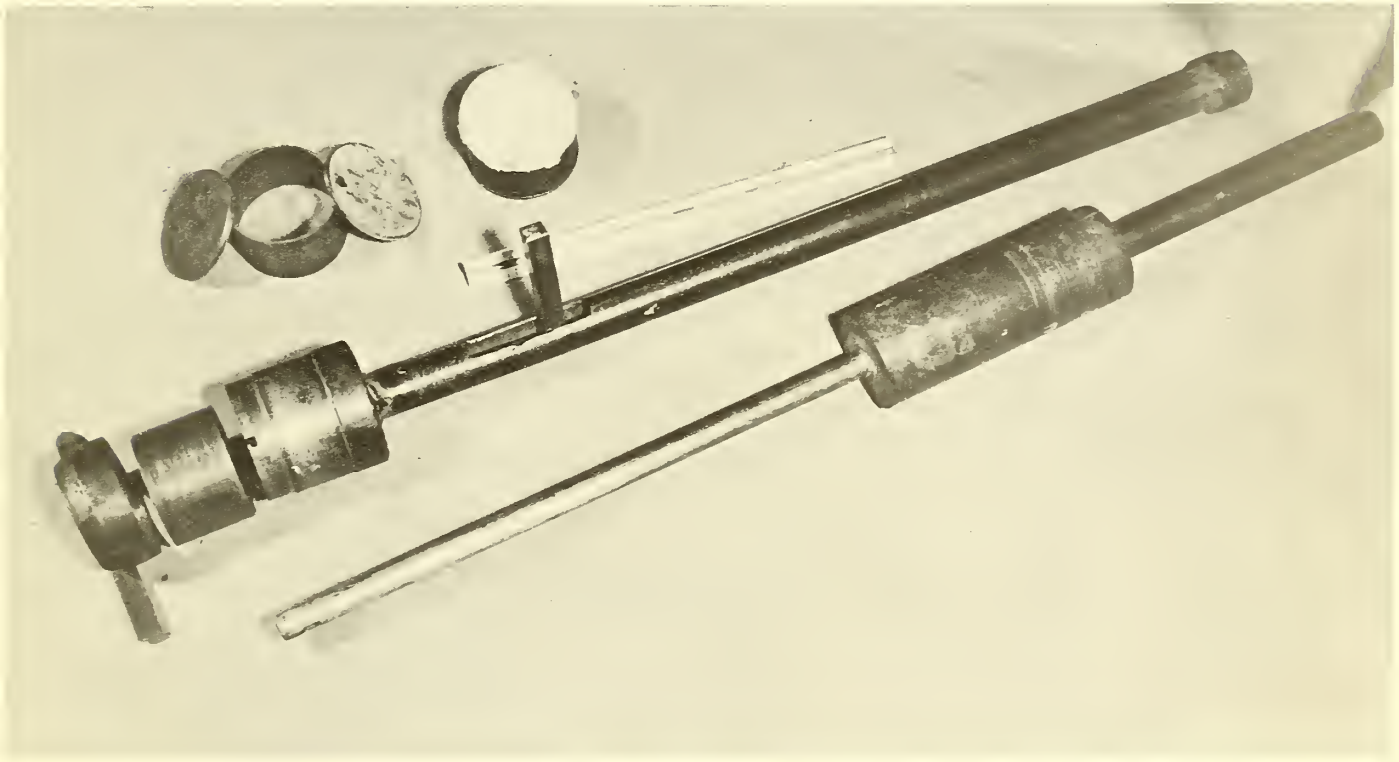


Figure 1.--Equipment used for collecting core samples in a pit. In the upper left hand corner is the empty copper cylinder with two lids. Next to it is a cylinder ready for saturation, inverted to show the cheesecloth on the bottom. In the middle is the soil sampler with copper cylinder and cutting head. At the bottom is the driving hammer. The long end of the hammer is inserted in the hollow handle of the sampler to drive it in the soil.

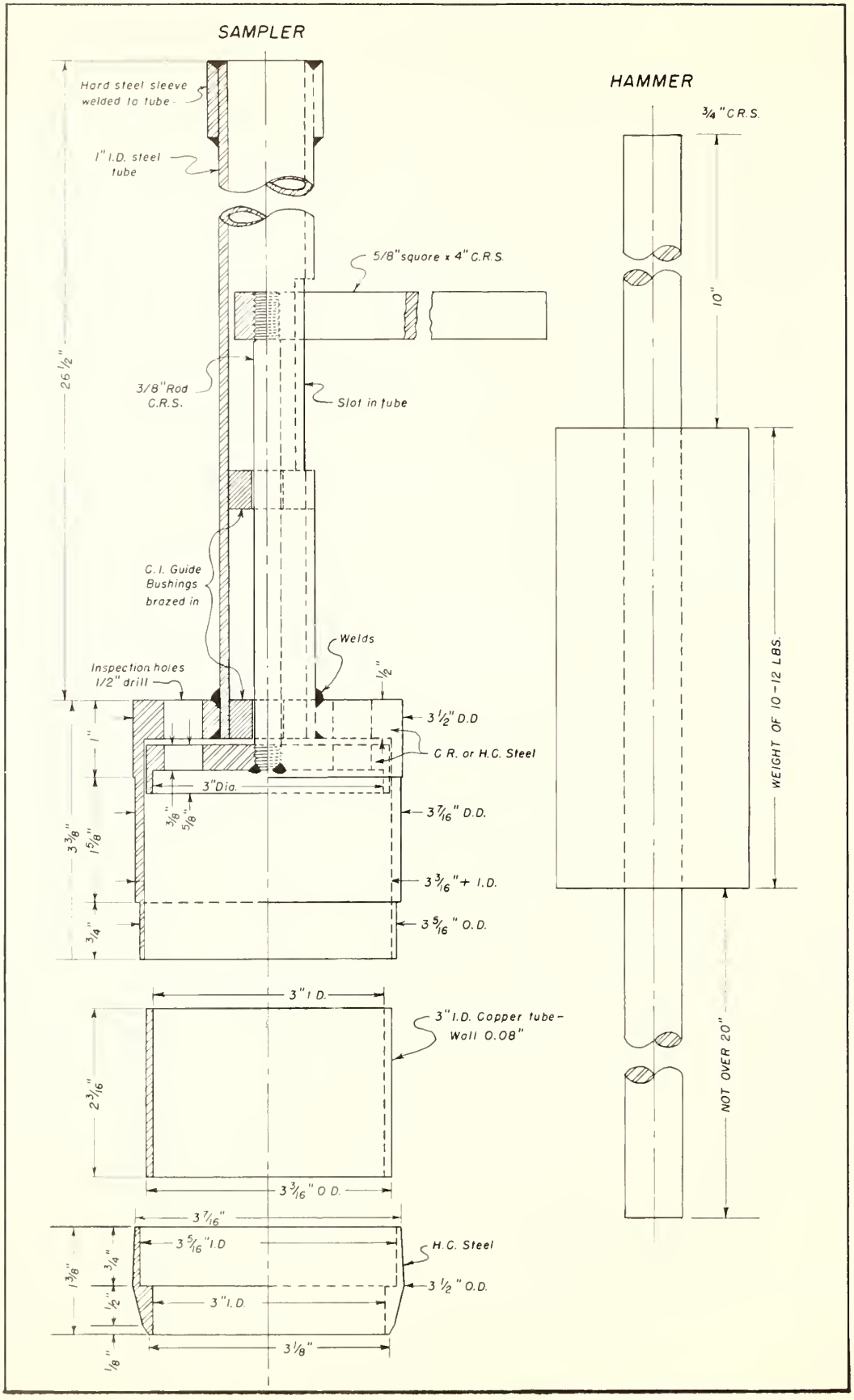
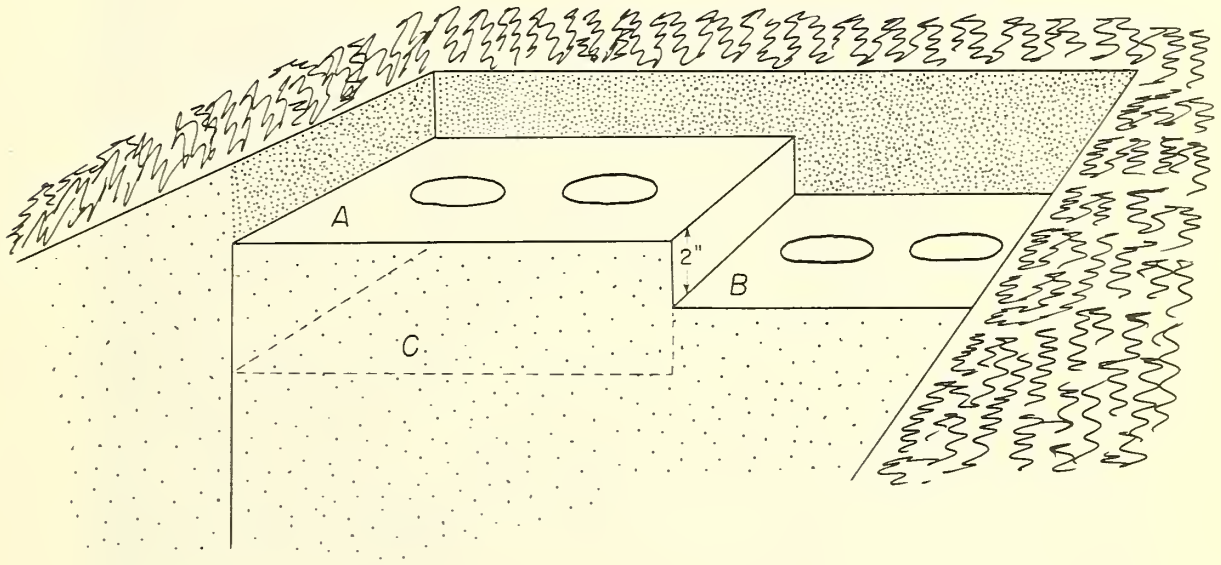


Figure 2.--Specifications for soil sampler.

The sampler is placed on a level surface and driven vertically into the soil. Figures 3 and 4 show the method of stepping down the pit face to obtain samples at various depths. A mark on the outside of the sampler and observation holes in the top of the sampler are used to gage the depth to drive the sampler. There is an extra clearance of 1/4 inch above the top of the copper cylinder so that the sampler can be driven deeply enough to insure filling the cylinder without compressing the soil sample. The sampler is removed by digging it out or more usually by moving the handle a few inches to break the sampler loose from the soil and then merely pulling it out.

The cutting head and the copper cylinder are both filled with soil. They are removed from the sampler by pushing a rod down through the handle. The top surface of the sample is then trimmed level with the cylinder and the top lid put on. A hack saw blade with the set ground off is ordinarily used for cutting away the soil and is held at an angle to prevent slicking the surface (fig. 5). Small scissors are convenient for cutting roots.



End and side face of original pit

New end and side face exposed as samples are collected

Ground surface

Plane *A* Horizontal face on which 2-4 inch samples have been collected

Plane *B* Horizontal face on which 4-6 inch samples have been collected

C Location of samples to be collected for 6-8 inch depth

Figure 3.--Diagram showing how pit face is sampled.

Figure 4.--Collecting soil samples near the surface. Man on left is steadying sampler and keeping it perpendicular while other man drives sampler into the ground with the driving hammer.

Figure 5.--Pit sampling in a broomsedge field. Man on left is cleaning out end of pit to proper depth for next sampling points. Other man is trimming sample which has just been collected. Long narrow box is useful for carrying equipment to the field.

The cylinder, with cutting head held by the included soil, is then turned over and the cutting head removed by holding down on the soil with both thumbs and pulling up the cutting head with the fingers. Excess soil is then cut away and the bottom lid put on.

Figures 6 and 7 show the field record sheet and the information collected at and in the vicinity of the pit.

Ordinarily for an individual pit 5 to 10 samples are collected from the 0 to 2-inch depth and 2 to 4 samples at each of the layers sampled below the surface. The depth of sampling and soil horizons sampled depend, of course, upon the purpose of the study. Samples taken in successive 2-inch layers provide the most information and should be taken when beginning work in a locality. Information thus collected will furnish a basis for future less intensive sampling.

Samples are placed in a box mounted on a backpack board to be returned to the laboratory. Rags are used to wedge the samples in the box and prevent jarring and loss of lids.

Sampling with the Utah Soil Sampling Machine[2/]

This soil sampling machine is essentially a hollow auger. A soil core is collected inside of a split brass tube which is restrained from rotation and settles down around the core as dirt is removed from around it by a cutting head. Details of this machine are described elsewhere (1).

2/ The Utah Soil Sampling Machine is made and sold by the Utah Scientific Foundation, Utah State Agricultural College, Logan, Utah.

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Soil Relations

FIELD RECORD OF SOIL PROFILE

Form 1.01 (1949)

Party L.J.M. - D.F.O.

Date Jan. 7, 1953

Profile No. 33

Sample No.	Depth Sampled	Notes
77	0-2	Loamy sand. Very pale brown, 10YR 7/4. Very compact.
89	4-6	Sandy clay loam. Yellow brown. 10YR 5/8. Compact.
229	8-10	Clay. Hard and brittle. Yellowish-red, 5YR 5/8.
176	46-48	Red clay. 2.5YR 5/6. Very tough + compact. Much mica present.

Profile Description

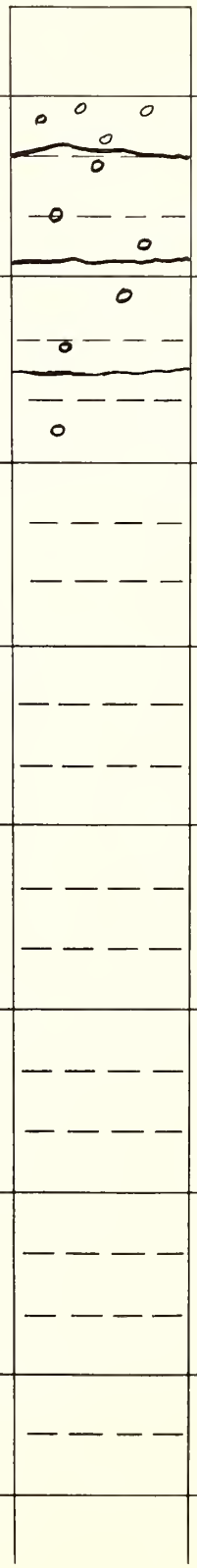

Figure 6.--Field record of soil profile.

Soil Relations Form 1.01 (B) (1949)

Profile No. _____

Date _____

Location										
Topography										
Slope Percent							Slope Direction			
Forest type, Land Use, and Condition										
History of Area										
Vegetation										
Trees on 1/10 acre plot									Minor Vegetation - milacre	
D.B.H.	Species								Species	Density
Sample Trees									Soil Series and Type	
Species	D.B.H.	Height	Age	Crown Class	Radial Growth				Erosion Class	
					5 Yr.	10 Yr.			Litter Depth	
									F - Layer	
									Humus Type	
									Soil biota	
									Notes	

Figure 7.--Field record of vegetation and other plot data. This is reverse side of form shown in figure 6.

The machine in use at Union takes a core 3.75 inches in diameter in lengths up to 6 feet. It is trailer mounted with its own power unit. A 1/4-ton jeep is ordinarily used to pull the trailer. Figure 8 shows machine in position in the field.

The most important advantage of the machine is that it collects an extremely good sample. It also saves time and labor so that a much greater number of samples can be collected when moisture conditions are favorable. The major disadvantages are high initial cost and the difficulty of getting the sampler to steep wooded locations. If a large sampling program is undertaken, the cost of the machine is soon offset by the saving in labor. It is possible to move the machine into situations too rough for a jeep because when the sampling tube is raised into working position the trailer is balanced and can be moved by two men. We have used a block and tackle to move it up steep slopes.

A soil core is cut to the desired depth and pulled from the ground. One half of the split brass tube is removed. The core is cut into 4-inch sections and the sections then coated with melted paraffin to preserve them for laboratory determinations. The paraffin is melted on a gasoline camp stove and the sections are coated by placing them in a wire basket which is briefly dipped into the paraffin. A paper tag is placed in the soft paraffin at the top of the sample at this time to identify the sample and to indicate the upper surface. When the wax has hardened, the sample is dipped again. Samples are transported to the laboratory in cardboard cartons containing excelsior for padding.

Figure 8.--The Utah soil sampler is position ready to dig a core. The sampler can remain attached to the jeep, shown on the left, during the drilling.

LABORATORY METHODS

The general laboratory procedure and methods are essentially similar regardless of which method is used to collect the sample. The procedure for samples collected from pits will be described in detail and necessary modifications for the machine samples discussed.

Sample Preparation

In the laboratory, the bottom lid is removed and replaced by a single thickness of cheesecloth. The cloth is first cut into 5 inch squares, then stretched over the cylinders, and held in place with a rubber band. Scissors are used to trim away the excess cheesecloth. At least one-quarter inch of cloth should be left above the rubber band to prevent slipping of the cloth. In handling samples, the fingers should grasp this cloth to prevent loss of the sample.

Fresh Weight

Samples are weighed to obtain fresh weight immediately after being fitted with cheesecloth. Fresh weight is recorded on the work sheet (fig. 9) and includes the weight of the copper cylinder, top lid, cheesecloth, and rubber band. A direct reading scale, such as the Toledo 4030Y, weighing to the nearest gram, speeds up the weighing job.

Saturation

Samples are saturated by placing them in water for 15 hours. They are set in 1/2 inch of water for 1 hour and then the water level is gradually raised to the top of the cylinder. To prevent air trapping, it is important that the water be kept from flooding over the top of the samples. Samples are saturated under atmospheric rather than reduced pressure because we feel this more nearly duplicates field conditions. The water used for saturation should be slightly warmer than the samples. Cooling during the saturation period prevents the formation of air bubbles within the soil core. Ordinarily, cores are saturated in the permeameter cup to be described later, but when large numbers of samples are run they are saturated in a shallow tank.

Percolation Determination

The apparatus for measuring percolation on the saturated soil cores is illustrated in figures 10, 11, 12, 13, 14, and 15. Top lids are removed and a head ring is fastened to the top of the cylinder with 1-inch-wide masking tape which is pressure-sensitive and waterproof. This tape forms a watertight seal and is convenient to use. The head rings were cut from the same copper pipe used to make the sampling cylinders. Copper tubing, 1/4 inch in diameter and 1-1/4 inches long is soldered to an opening on the side of the head ring for the entrance of water. The sample with head ring attached is placed in the permeameter cup. The hose at the bottom of the cup is closed with a pinch clamp and the sample saturated by adding water to the cup. When saturation is complete, a rubber tube is used to connect the head ring to a constant head tank. After the head was built up on top of the sample, the lower tube is opened to drain off excess water. This procedure prevents

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Soil Relations SOIL PROFILE SAMPLING WORK SHEET

Form 1.02(1949)

Sampled by L.J.M. - D.F.O.

Sample No. (1)	Depth of sample (2) inches	Fresh weight (3) gms.	Saturated weight (4) gms.	Weight after 20 cm. (5) gms.	Amount drained 20 cm. (6) gms.	Weight after 60 cm. (7) gms.	Amount drained 60 cm. (8) gms.	Gross O.D. weight (9) gms.	Weight rocks (10) gms.	Tare (11) gms.	
77	0-2	645.1	719.8	682.5	37.3	656.0	63.8	616.1	8.7	284.2	
89	4-6	741.8	767.2	749.8	17.4	746.5	20.7	676.7	6.8	286.2	
229	8-10	718.7	761.0	746.4	15.6	743.0	18.0	644.1	3.2	291.2	
176	46-48	708.1	762.2	745.4	16.8	739.5	22.7	639.0	3.3	290.7	

EXPLANATION OF COLUMNS

1. Number of copper cylinder.
2. Depth of sample.
3. Weight when first brought in from field. Includes cylinder, soil, one lid, cheesecloth, and rubber band.
4. Weight at end of percolation run when sample is saturated.
5. Weight after being at 20 cm. tension for 2 hours.
6. Column 4 — column 5.
7. Weight after equilibrium at 60 cm. tension.
8. Column 4 — column 7.
9. Weight after oven drying to constant weight.
10. Dry weight of all material in soil sample retained on 2 mm. sieve.
11. Weight of copper cylinder, one lid, cheesecloth, and rubber band.

Figure 9.--Soil profile sampling work sheet.

Profile No. 33

Date sampled Jan. 7, 1953

Computer W. P. B. Checked by W.C.

	Net O.D. weight	Volume corrected for rock	Volume weight	Field moisture		Moisture at saturation		Retention at 60 cm.		Detention	
										20 cm.	60 cm.
	(12) gms.	(13) ml.	(14)	(15) gms.	(16) pv	(17) gms.	(18) pv	(19) gms.	(20) pv	(21) pv	(22) pv
	323.2	246.7	1.31	29.0	11.8	103.7	42.0	39.9	16.2	15.1	25.9
	383.7	247.5	1.55	65.1	26.3	90.5	36.6	69.8	28.2	7.0	8.4
	349.7	248.7	1.41	74.6	30.0	116.9	47.0	98.9	39.8	6.3	7.2
	345.0	248.7	1.39	69.1	27.8	123.2	49.6	100.5	40.5	6.8	9.1

EXPLANATION OF COLUMNS

12. Column 9 — (column 10 + column 11).
13. Taken from table 2.
14. Column 12 ÷ column 13.
15. Column 3 — column 9.
16. (Column 15 ÷ column 13) x 100, or column 15 x value in table 3 found under rock weight of 8.6 grams.
17. Column 4 — column 9.
18. (Column 17 ÷ column 13) x 100, or column 15 x value used to compute column 16.
19. Column 7 — column 9.
20. (Column 19 ÷ column 13) x 100, or column 19 x value used to compute column 16.
21. (Column 6 ÷ column 13) x 100, or column 6 x value used to compute column 16.
22. (Column 8 ÷ column 13) x 100, or column 8 x value used to compute column 16.

Figure 9 (Continued).

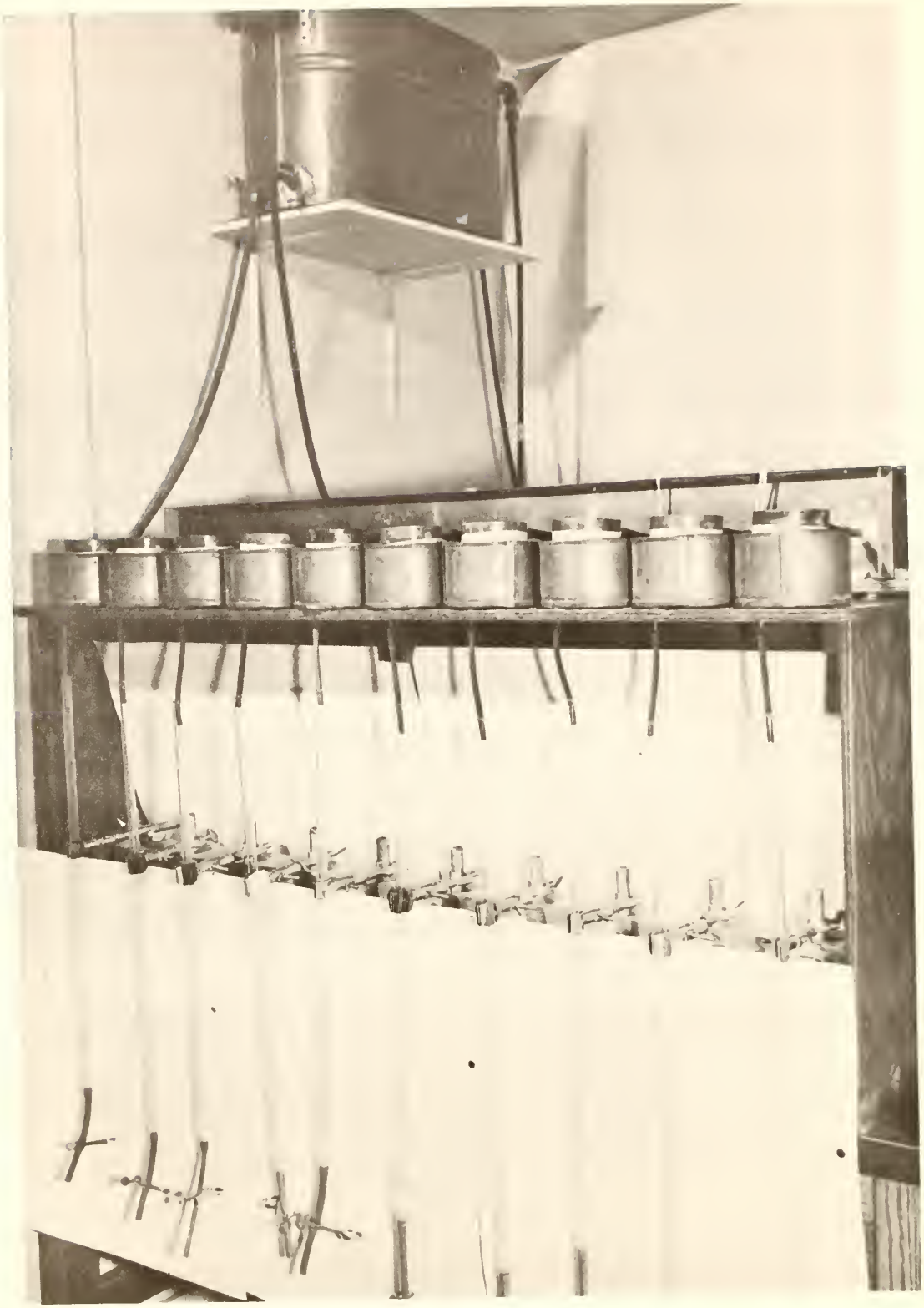


Figure 10.--View of one side of constant head permeameter apparatus. Tank at top in rear supplies water to the constant head tank. Thermometer at right end of constant head tank measures temperature of water during runs.

Figure 11.--Equipment used to hold sample during percolation runs. The head ring on the left is attached with masking tape to the soil cylinder after its top lid has been removed. Cylinder with attached head ring is then placed in the permeameter shown at right.

air from entering the sample. As can be seen from figure 15, the lower end of the sample is covered by water when the excess water has drained away and there is no air interface at either end of the sample.

Water is allowed to percolate through the sample for a period of 5 to 10 minutes before the timed percolation rate begins. This allows the rate to stabilize and also permits the operator to form an estimate of the percolation rate to determine whether the percolate can be held in the 50 ml. burette or whether a graduate with larger capacity should be used.

Five samples can be handled at a time by one man by beginning timed runs 1 minute apart. The volume of percolate is measured at intervals of 5, 10, and 20 minutes. The average for the 20-minute run is ordinarily used for calculation. Measurements for other periods serve as a check on the performance of the sample and if excessive deviations occur between time periods, leakage or breakdown of soil structure are indicated. When flow through the sample is rapid--more than 100 ml. per minute--percolation is allowed to continue only 5 to 10 minutes to minimize disturbance to the sample. For surface samples from hardwood forest, or in other situations where rapid percolation is expected, head on the sample is reduced by fitting an extension to the outflow tube of the permeameter.

All results are converted to inches per hour at unit head and corrected to a water temperature of 60° so that all determinations are comparable. Unit head is defined as the head equal to the length of the soil core itself.

$$\text{Rate at unit head} = \frac{\text{length of sample}}{\text{total head on sample}} \times \text{measured rate.}$$

The total head on the sample is the difference in elevation between the water in the head ring and that in the permeameter cup outside the sample. The routine head used is 6.5 cm. or 1 cm. more than the length of the sample. The correction to unit head is then $5.5 \div 6.5$ or .846, which is the factor by which measured flow is multiplied to obtain flow at unit head.

The conversion to inches per hour is made by determining the volume in ml. of a depth of 1 inch on the soil core. Samples from the hand sampler have an end area of 45.36 sq. cm., which when multiplied by 2.54, the number of centimeters in 1 inch, gives a product of 115.21 ml. Dividing the volume of 115.21 ml. by 60 minutes gives a flow of 1.920 ml. per minute equal to a 1 inch per hour percolation rate. The average flow per minute in ml. divided by 1.920 gives the average percolation rate in inches per hour. In practice, it is more convenient to multiply by the reciprocal of 1.920, which is 0.520, than to perform the division.

The correction for the effect of temperature upon viscosity of the water is:

$$\text{Viscosity factor} = \frac{\text{viscosity of water at test water temperature}}{\text{viscosity of water at } 60^{\circ}\text{F.}}$$

Measured flow is multiplied by this factor to correct it to the flow which would occur at 60°F. This correction is important in field laboratories, where the temperature of the water may vary greatly at different seasons of the year. The temperature of 60°F. is the standard used by the Geological Survey in their permeability investigations.

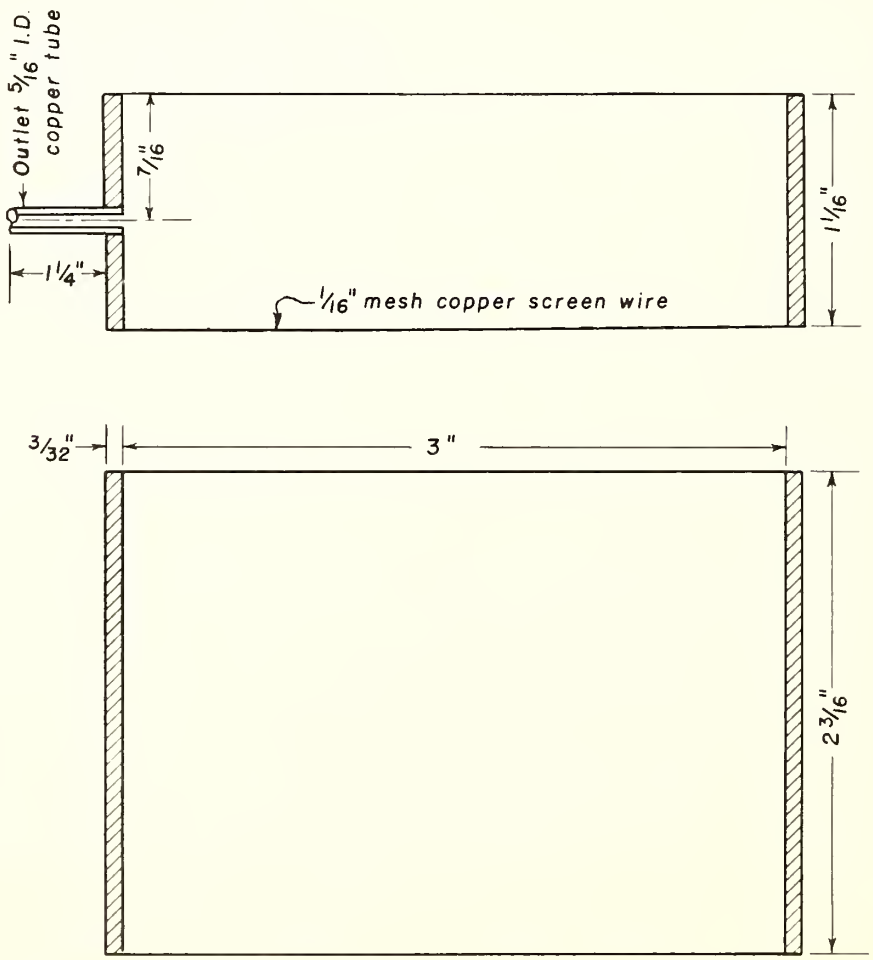
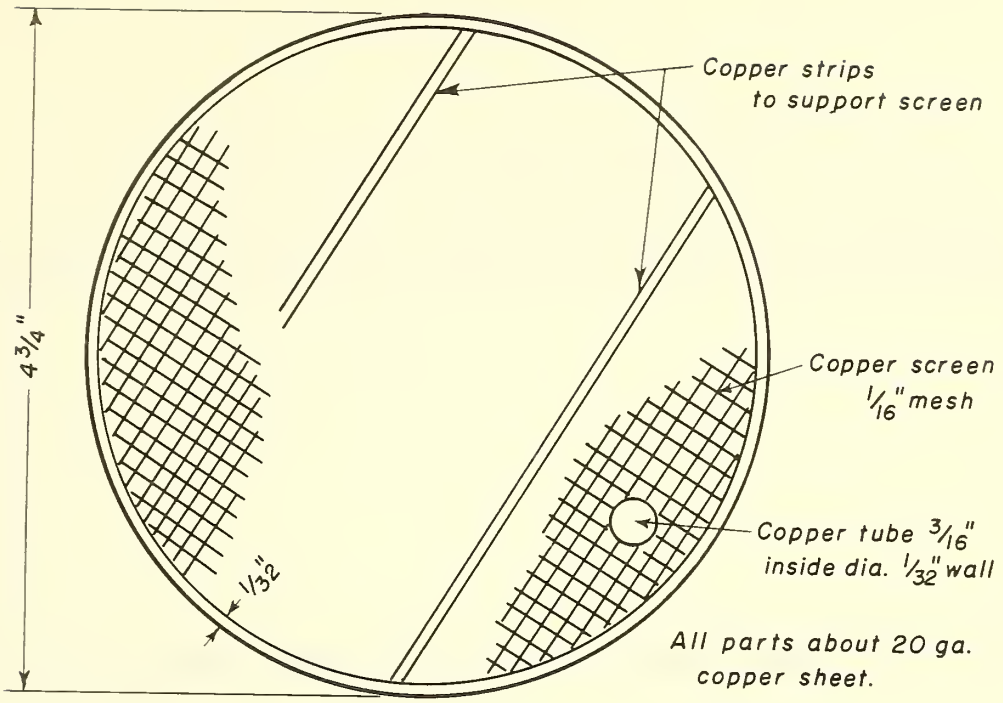


Figure 12.--Cross section of head ring and sampling cylinder shown in figure 11. The outlet tube and copper screen are soldered to the head ring.

PERMEAMETER

Top View



Side View

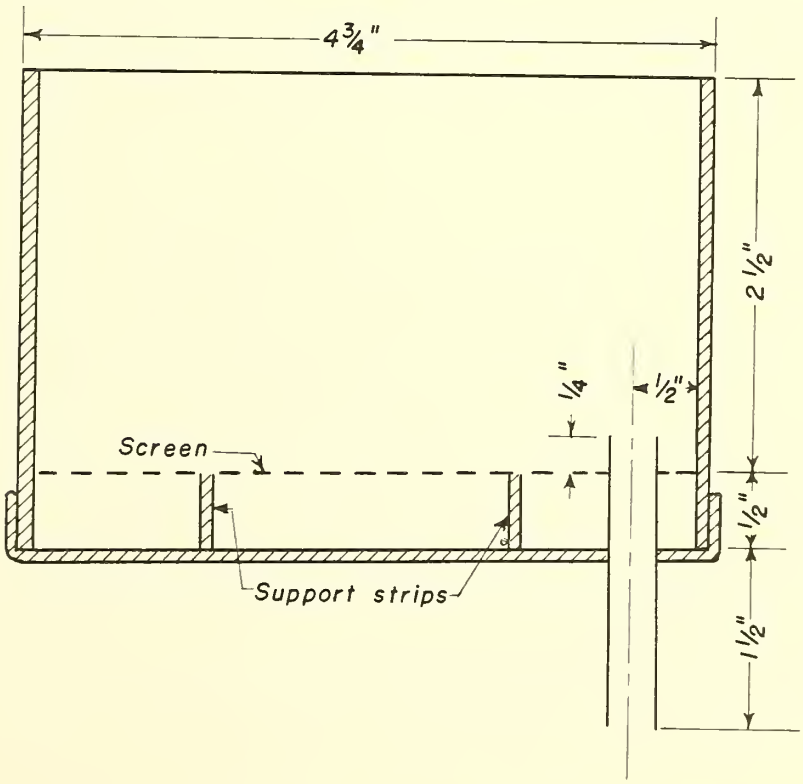
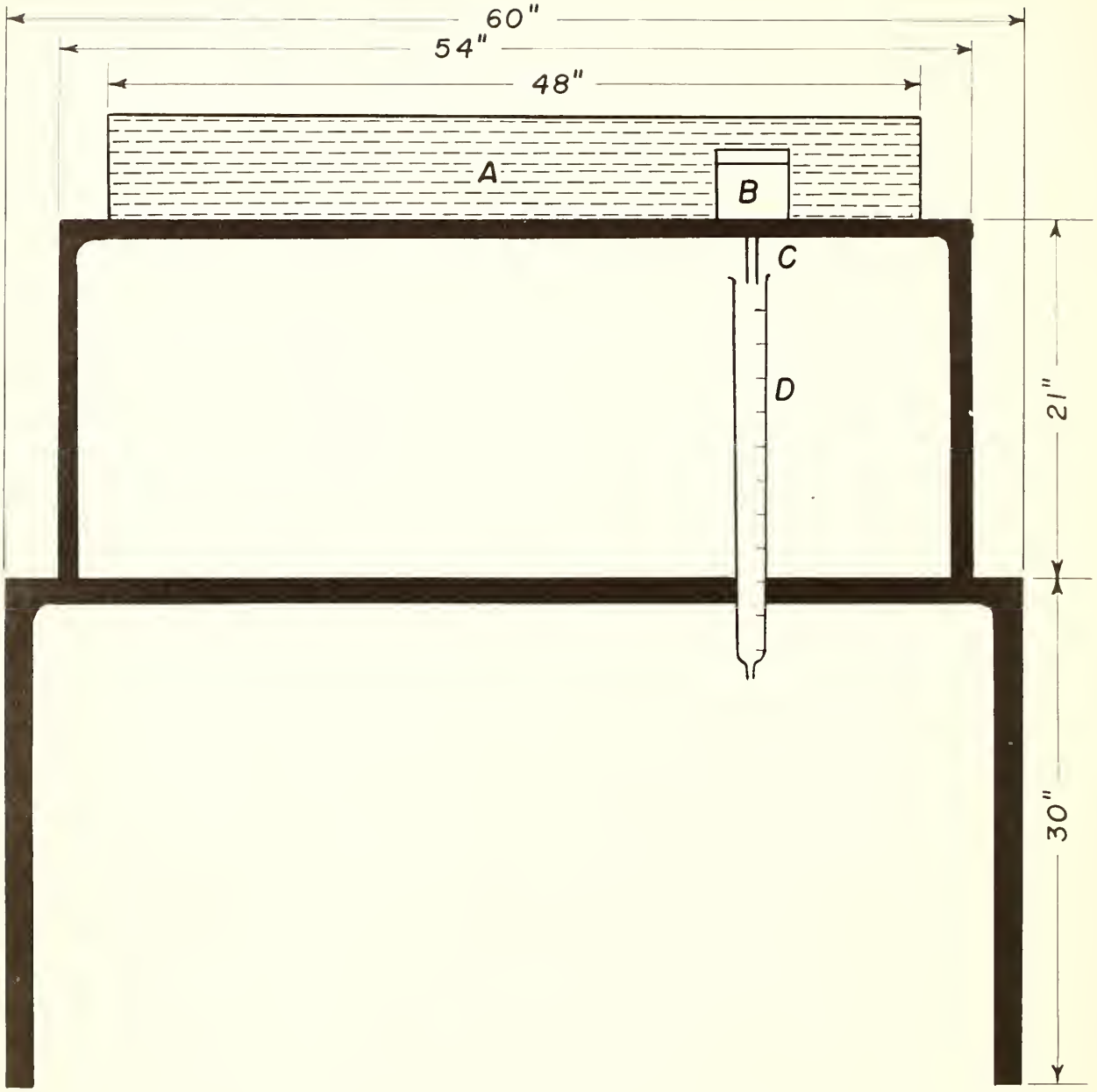


Figure 13.--Diagramatic views of permeameter shown in figure 11.



A CONSTANT LEVEL TANK 5" DEEP, 5" WIDE

B PERMEAMETER WITH HEAD RING ATTACHED

C OUTFLOW TUBE

D BURETTE OR GRADUATE

Figure 14.--Permeability apparatus, side view.

The form used to record percolation measurements is shown in figure 16. The conversion of flow rates to inches per hour, and corrections for head and viscosity can be readily made by means of tables such as table 1, which greatly simplify the calculations.

Pore Space Determination

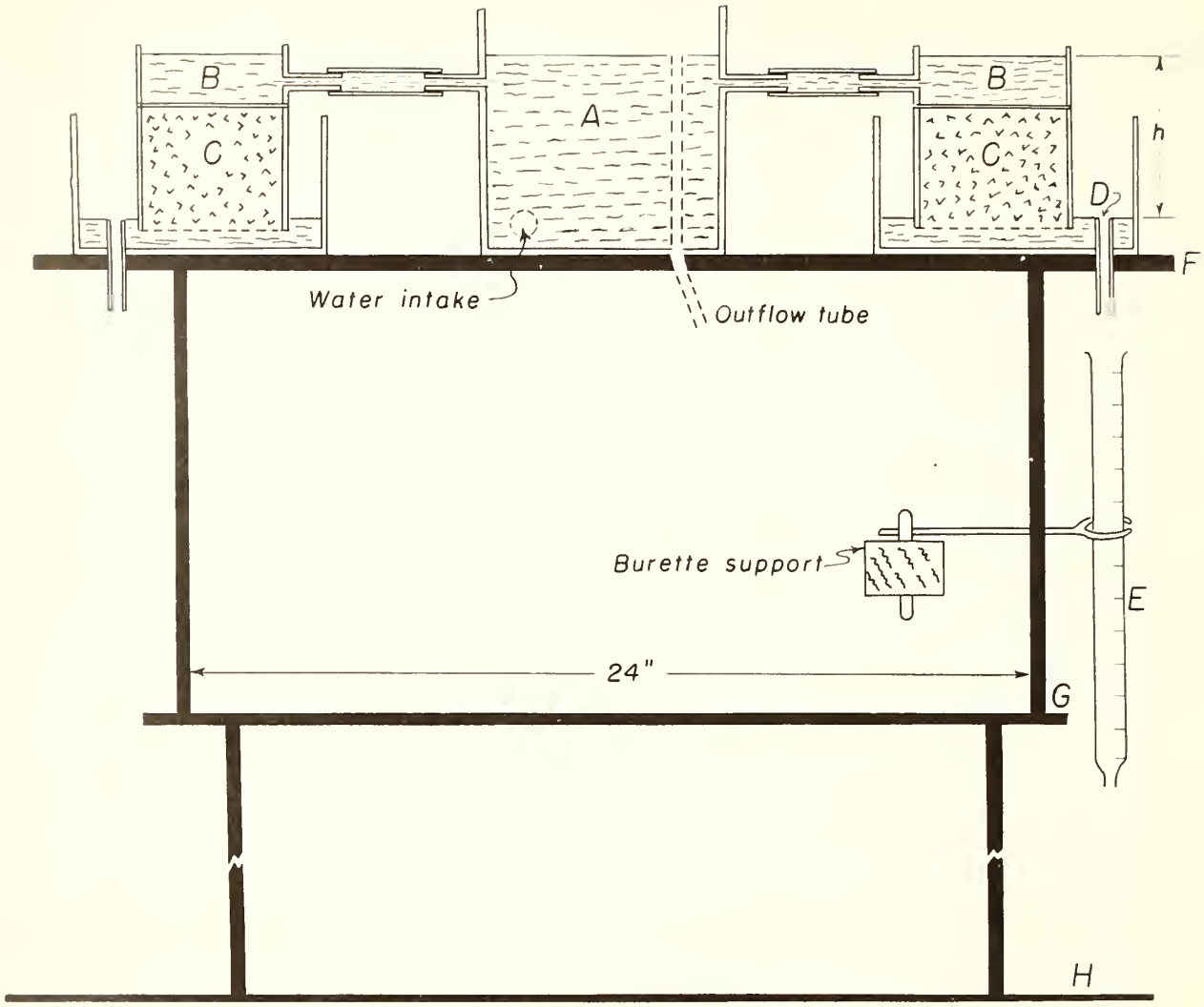
When the percolation measurement is completed, the connection from the constant head tank and the outflow tube are closed by tubing clamps. The head ring and masking tape are removed and the top lid is replaced on the cylinder. The permeameter cup is filled with water to the full height of the sample to saturate the sample. The saturated weight of the sample is obtained by quickly lifting the sample from the permeameter cup and placing it on a weighing pan. The sample and the water draining from its large voids onto the weighing pan are weighed, and the weight is recorded on the work sheet, figure 9. Samples are then placed in an open tank with one-half inch of water in it to keep them moist and to hold them so that they can be set upon the blotter-tension table at about the same time.

The blotter-tension tables are similar to that described by Leamer and Shaw (2). However, the base of the table is glass instead of sheet metal so that it is possible to inspect from below to see whether air bubbles are present under the blotter. The glass outlet tube is sealed to a hole in the center of the glass with ordinary red sealing wax. Figures 17 and 18 show the tension tables.

The plate glass is 23 inches by 29 inches and is fitted inside a wooden frame so that water can be ponded upon the glass. Photographic lintless blotters 20 by 24 inches have been found most convenient to use. The screen beneath the blotter is 15 by 19 inches, which allows a blotter overlap of 2-1/2 inches all around for adhesion to the glass. Plastic window screen is the best because it does not oxidize and is extremely flexible.

A filter flask is used for the leveling bottle and the difference in level between the outflow tube of the filter flask and the top of the blotter is the measure of the tension at which the sample is drained. The filter flask is fitted with a 3 hole rubber stopper to hold 3 glass tubes. Two tubes end above the outflow level of the flask. One of these is an air vent. The other is connected to a water reservoir by a rubber tube. A clamp adjusts the flow from the water reservoir to a slow drip, to keep water level constant in the leveling bottle and to replace evaporation losses from the blotter. The third glass tube extends to the bottom of the flask and is connected to the outlet from the tension table.

To set up the table, the glass is first thoroughly cleaned to insure good adhesion of the blotter beyond the margin of the screen. The air vent and outflow of the level bottle are then closed and the supply line from the water reservoir opened. This forces water to the top of the glass and removes air bubbles from the system. Water is allowed to flow until it reaches a depth of about 1/4 inch on the glass. The screen is then set in place and air bubbles removed by rubbing with the fingers. The blotter is set down first at one edge, and as it wets it becomes flexible and is allowed to settle in place. When the blotter is down, a roller is



A Constant head tank

B Head ring held to sampling cylinder by masking tape

C Soil sample and sampling cylinder resting on screen

D Outflow tube for permeameter

E Burette or graduate

F Top of upper table

G Top of lower table

H Floor

h Total head of water on sample

Figure 15.--Permeability apparatus, end view.

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Form 1.03(1949)

PERCOLATION MEASUREMENT

Profile No. 33

Date sampled Jan. 7, 1953

Sample No.	Depth	Head	Water temp.	Measured flow at time				Average measured	Rate at unit head	
				Start	5 min.	10 min.	20 min.			
(1)	(2) inches	(3) cm.	(4) °F.	(5) ml.	(6) ml.	(7) ml.	(8) ml.	(9) ml./min.	(10) i.p.h.	
77	0-2	6.5	70	0	100	195	38.5	19.25	7.39	
89	4-6	6.5	70	50.0	37.8	26.9	7.3	2.14	0.82	
229	8-10	6.5	59	50.0	49.3	48.6	47.4	0.13	0.06	
176	46-48	6.5	58	50.0	49.4	48.9	48.1	0.10	0.05	

EXPLANATION OF COLUMNS

1. Number of copper cylinder.
2. Depth of sample.
3. Height of water column used.
4. Temperature of water during run.
5. Reading on burette when run begins.
6. Reading on burette at end of 5 minutes.
7. Reading on burette at end of 10 minutes.
8. Reading on burette at end of 20 minutes.
9. (Column 5 — column 8) ÷ 20.
10. Column 9 x factor in table 1 corresponding to water temperature during run.

Figure 16.--Data sheet for percolation measurement.

run over it to force out any air bubbles. Excess water is allowed to drain out through the leveling bottle. As the excess water drains away, the roller is used to press the margin of the blotter firmly to the glass. A check is made by looking up from below, and, if no air bubbles are present below the blotter and the outflow tube from the table is filled with water, the table is ready for use.

When tension is established, the soil cores are placed on the top of the blotter with sufficient downward pressure to make a good contact between the sample and the blotter. The leveling bottle is then set to provide 20 cm. of water tension on the sample and after 2 hours' drainage the samples are weighed and the weight recorded on the work sheet. The cores are then replaced on the blotter and the leveling bottle is lowered to provide 60 cm. tension. This tension is maintained overnight, or for 15 hours, which is the equilibrium value at this tension for most soils. In fact, for many of the clay subsoils of the Piedmont equilibrium is reached after 2 hours of the 60 cm. tension.

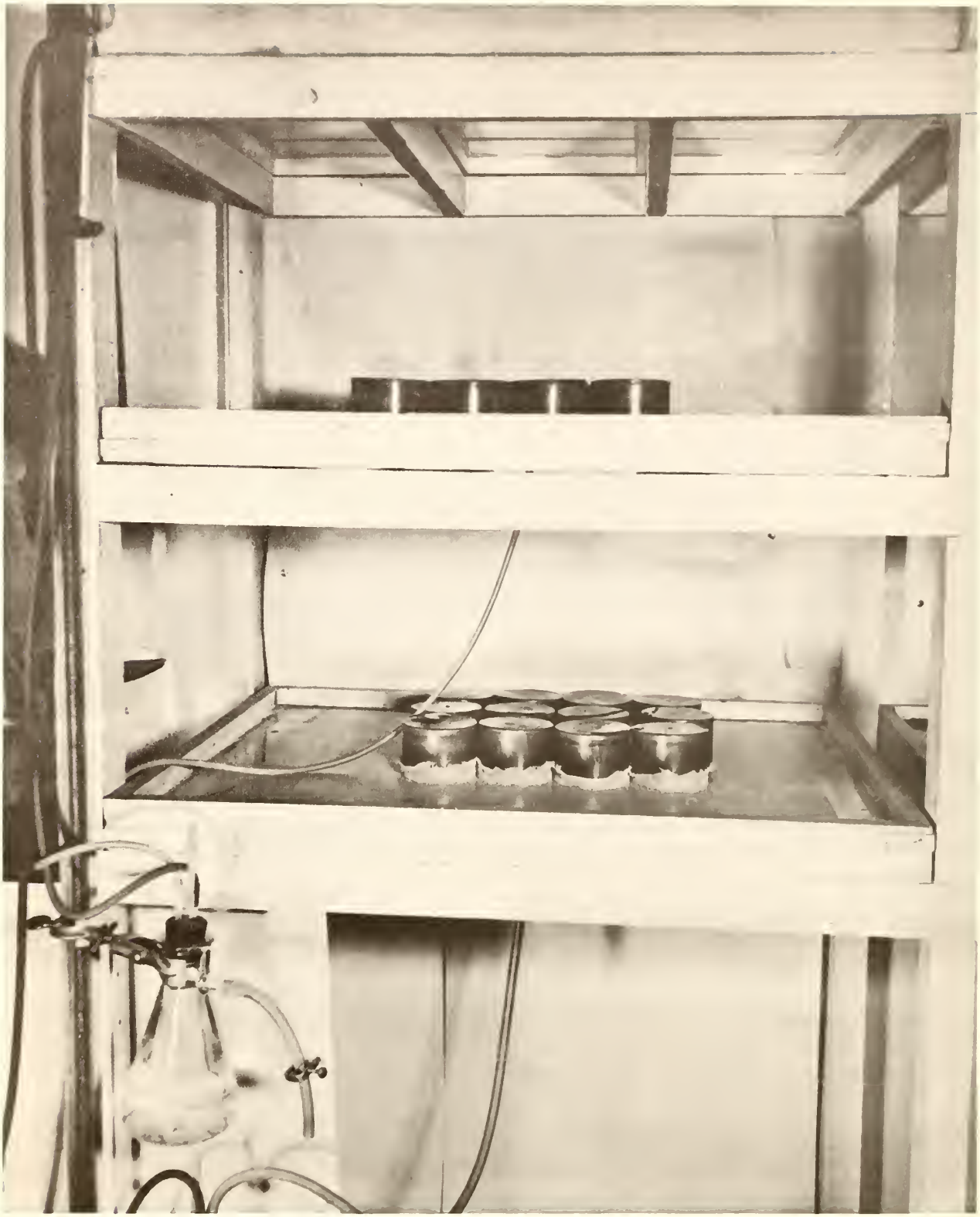

Figure 17.--Three tension tables with bottom two in operation. Leveling bottle shown is for the middle table. The reservoir bottle is on the top table. Markings to show where to place leveling bottle for tension desired are on wooden stick next to iron bar which supports the bottle.

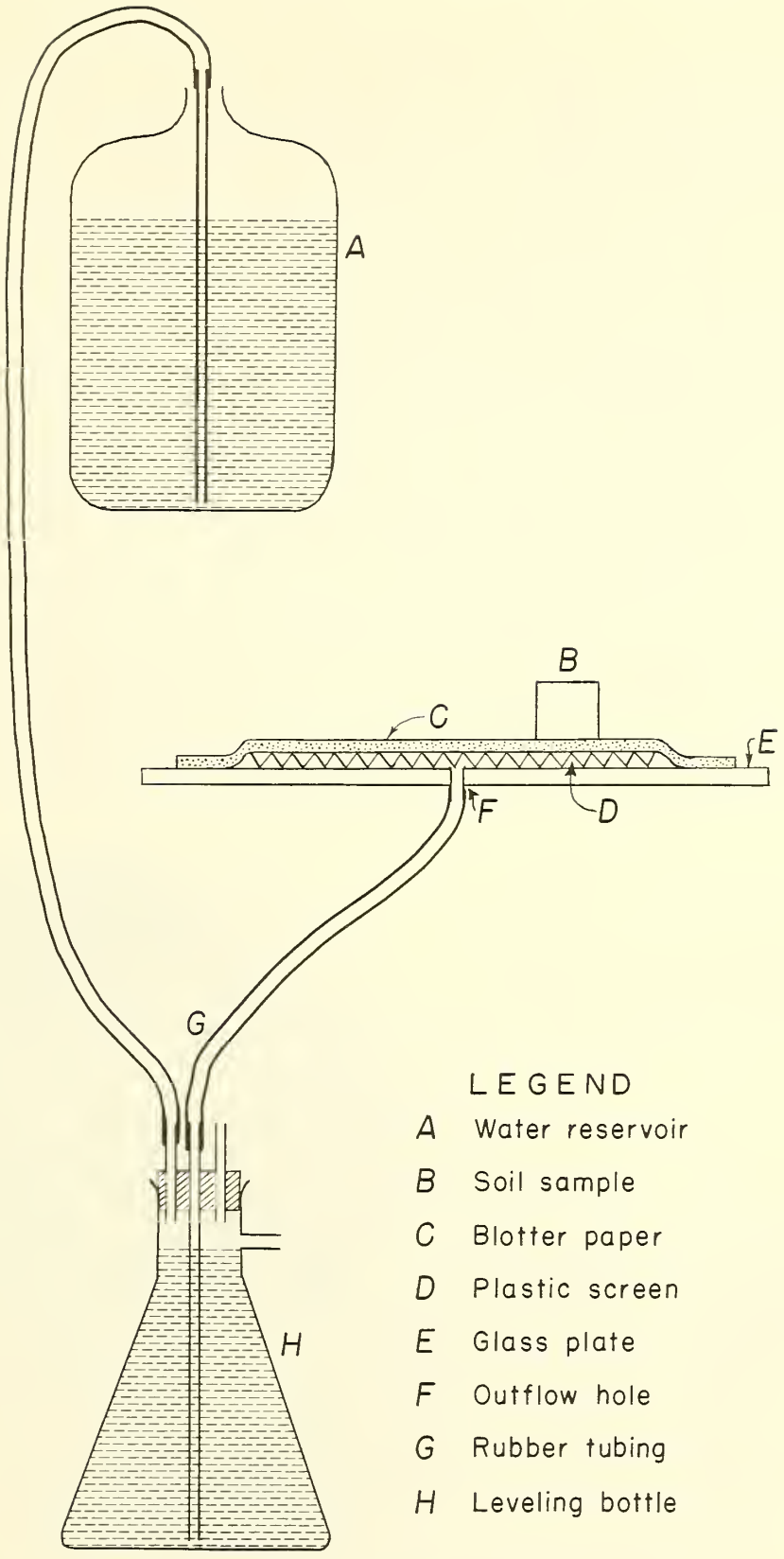

Figure 18.--Schematic diagram of tension table.

When the 60 cm. tension determination is complete, the samples are weighed and then dried to constant weight at 105°C. With a forced draft, oven drying is completed within 15 hours if the top lid is removed. The oven-dry weight of sample plus tare is recorded on the work sheet. Tare weights of cylinders and lids are tabulated to save repeated weighings but are checked at frequent intervals. An arbitrary standard weight is assigned to cheesecloth and rubber bands, based on frequent checks.

Modification of Procedure for Samples Collected by Machine

At the laboratory, the wax coated samples from the soil sampling machine are first trimmed to a length of 3 inches. A sample is put into a cutting cylinder made from a galvanized sheet metal strip 3 inches wide (fig. 19). Two bolts pass through ears on the outside of the cylinder so that it can be adjusted for diameter. These bolts are tightened so that the core is firmly held, and the sample is trimmed even with each end of the cylinder. The sample is then placed with the top up into another cylinder of similar construction but 5 inches high. This cylinder holds the core during percolation and pore space determination. It is fitted with a copper tube connection to the constant head tank of the percolation apparatus. The lower end of the sample is covered with cheesecloth held on by a rubber band, as with the other samples. A narrow ring of melted paraffin is applied with a brush at the top of the sample to seal the space between the metal container and the paraffin coating on the sides of the soil core. Laboratory measurements and calculations are similar to those described for other samples.

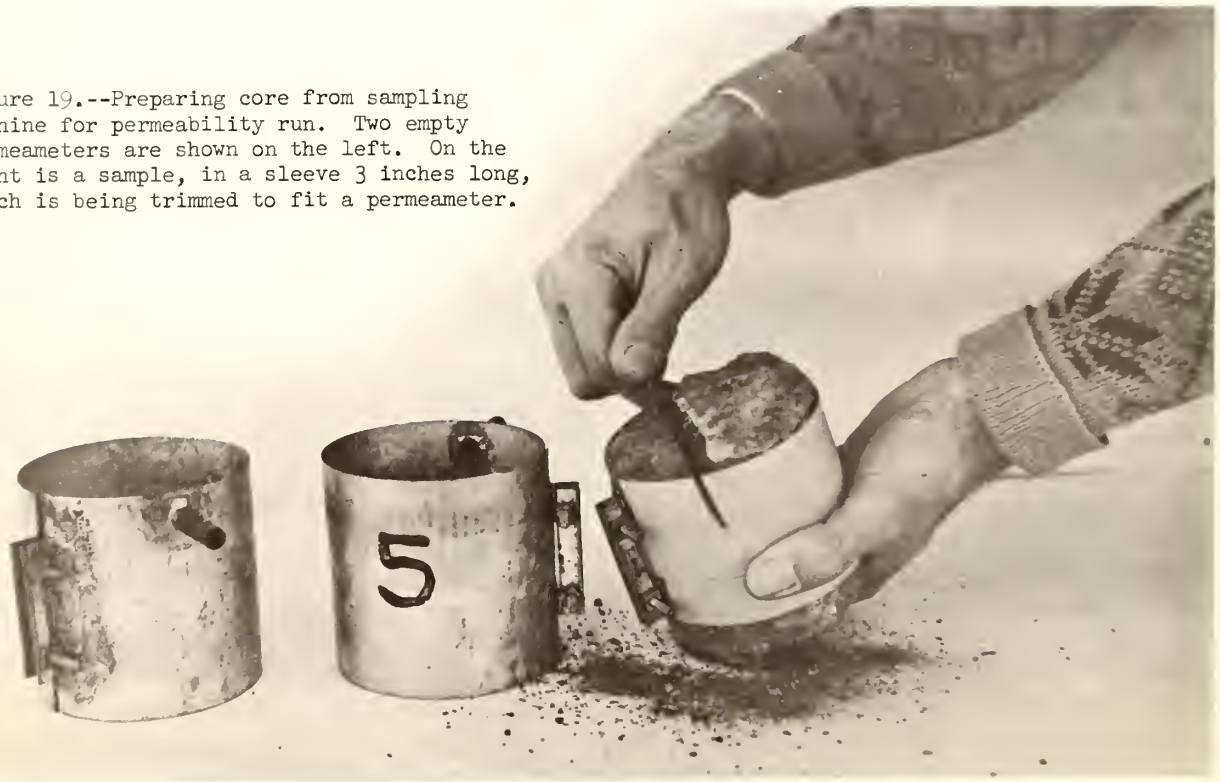

Figure 19.--Preparing core from sampling machine for permeability run. Two empty permeameters are shown on the left. On the right is a sample, in a sleeve 3 inches long, which is being trimmed to fit a permeameter.

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EXAMINATION OF SAMPLES

Soil Profile 33
Date sampled Jan. 7, 1953
Sampled by LJM - DFO
Examined by LJM

Sample No. (1)	Depth sampled (2)	Perc. rate (3)	Texture (4)	Color (5)	Notes (6)
77	0-2	7.39	Loamy Sand	U. pale brown 10YR 7/3	Good sample. Single grained structure. Two horizontal roots about 2 mm dia. No evidence of soil fauna.
89	4-6	0.82	S.c.l. to clay	U. pale brown 10YR 7/4	Good sample. Coarse granular structure.
229	8-10	0.06	clay	light red 2.5YR 6/6	Good sample. Blocky structure. No roots.
176	46-48	0.05	clay	Reddish yellow 5YR 7/6	Good sample. Tough, platy structure. Fractures along schist banks. Highly micaceous.

EXPLANATION OF COLUMNS

1. Sample number.
2. Sample depth.
3. Percolation rate, from column 11 figure 16.
4. Texture.
5. Color of dry soil from Munsell Book of Color.
6. Description of sample.

Figure 20.--Sheet for recording percolation rate and observations made before and after oven-dry sample is broken open. Information in column 6 helps locate samples to be rejected in computing averages.

Examination of Samples and Sieving of Rock

After the oven-dry weight of the samples is obtained, they are removed from the cylinders and carefully examined for flaws which could have affected the measured percolation rate. Leakage of water between the cylinder and edge of core is usually shown by erosion marks along the edge of the core. Also noted are the presence of root or animal passageways continuous enough to affect water movement. This information is recorded (fig. 20) along with oven-dry soil color, texture, and structure, and is well worth the time required, as it provides considerable information for the investigator and prevents use of doubtful samples in obtaining averages for a profile. Each

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SOIL PROFILE MEASUREMENTS

Profile No. 33
Date sampled Jan. 7, 1953
Sampled by L.J.M. - O.F.O.
Computation by W.P.B.
Checked by W.C.

Form 1.04(1949)

Sample No. (1)	Depth sampled (2) inches	Fresh moisture content (3) pv	Volume weight (4)	Calc. porosity (5) pv	Saturated pore space (6) pv	Retention at 60 cm. (7) pv	Detention		Percolation at unit head (10) i.p.h.		
							20 cm. (8) pv	60 cm. (9) pv			
77	0-2	11.8	1.31	50.6	42.0	16.2	15.1	25.9	7.39		
89	4-6	26.3	1.55	41.5	36.6	28.2	7.0	8.4	0.82		
229	8-10	30.0	1.41	46.8	47.0	39.8	6.3	7.2	0.06		
176	46-48	27.8	1.39	47.5	49.6	40.5	6.8	9.1	0.05		

EXPLANATION OF COLUMNS

1. Number of copper cylinder.
2. Depth of sample.
3. Column 16 on figure 9.
4. Column 14 on figure 9.
5. From table 4.
6. Column 18 on figure 9.
7. Column 20 on figure 9.
8. Column 21 on figure 9.
9. Column 22 on figure 9.
10. Column 11 on figure 16.

Figure 21.--Summary sheet of soil profile measurements.

sample is then slaked in water and washed through a 2 mm. screen. Particles larger than 2 mm., which are considered as rock, are dried and weighed. The weight of rock is shown on the work sheet. The purpose of determining rock is to compare samples on a rock-free basis. This removes much erratic variation in comparison of bulk density. When sufficient sampling has been done at a site, average values of rock are determined for the horizons sampled. These averages are used to adjust bulk density and other constants to prevailing field values.

Computational Methods

Percolation computations have been described for the pit samples. Other calculations are shown in figure 9. To simplify calculations, tables 2, 3, and 4 have been made and are included with this paper. Reciprocals are used where division is indicated, to speed up operations on a calculating machine. Figure 21 shows the final summary form used to show the results of determinations for a soil profile. All percent values are given as percent of soil volume (Pv.).

Table 1.--Factors for converting percolation rate in cubic centimeters per minute at test temperature to inches per hour at unit head at 60°F. Used for 250 cc. samples[1/]

Water Temp. (°F.)	0	1	2	3	4	5	6	7	8	9
	Factors									
40	.606	.595	.585	.575	.565	.556	.547	.538	.529	.521
50	.513	.505	.497	.489	.482	.474	.467	.460	.454	.447
60	.440	.434	.428	.422	.416	.411	.405	.400	.394	.389
70	.384	.379	.374	.369	.364	.359	.355	.350	.345	.341
80	.337	.333	.329	.325	.321	.318	.314	.310	.307	.303

1/ Values in top row and left column are degrees F. Tabulated values are conversion factors. The product of factor and cc. per minute is inches per hour corrected for head and temperature. Example: If measured percolation rate is Y cc. per minute and water temperature is 62°F., then Y times 0.428 equals inches per hour at unit head at 60°F.

Table 2.--Volume of soil in 250 cc. sample when the weight of rock in the sample is known[1/]

Weight of rock (grams)	0	1	2	3	4	5	6	7	8	9
	Volume of soil in cc.									
0	250.0	249.6	249.2	248.8	248.5	248.1	247.7	247.4	247.0	246.6
10	246.2	245.9	245.5	245.1	244.7	244.3	244.0	243.6	243.2	242.8
20	242.5	242.1	241.7	241.3	241.0	240.6	240.2	239.8	239.4	239.1
etc.										

1/ Values in top row and left column are weight of rock in sample in grams. Tabulated values give volume of sample minus volume of rock. Basis for computing values in table is volume of soil sample minus weight of the rock divided by specific gravity of the rock or

$$\text{Volume of soil in sample} = 250 - \left(\frac{\text{wt. of rock}}{2.65}\right)$$

In reciprocal form this becomes Volume of soil in sample = 250 - .377 (weight of rock). Example: After sieving soil sample, 11 grams of material is retained on the 2 mm. sieve. Opposite 11 grams of rock in the table is the volume of soil in the sample, 245.9 cc.

Table 3.--Factors for calculating percent by volume corrected for rock[1/]

Weight of rock (grams)	0	1	2	3	4	5	6	7	8	9
					Factors					
0	.40000	.40064	.40128	.40193	.40241	.40306	.40371	.40420	.40486	.40552
10	.40617	.40667	.40733	.40800	.40866	.40933	.40984	.41051	.41118	.41186
20	.41237	.41305	.41374	.41442	.41494	.41563	.41632	.41701	.41771	.41824
etc.										

1/ Values in left column and top row are weight of rock in grams in the sample. Tabulated values are reciprocal of volumes corrected for rock (table 2) times 100. Use of this table shortens computational time, as multiplication is substituted for division. Example: If a sample has a field moisture content of Y grams of water but contains 12 grams of rock, then Y times 0.40773 is the field moisture content in percent by volume of the rock-free soil.

Table 4.--Porosity of sample based on bulk density[1/]

Bulk density	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
					Percent porosity					
.90	66.0	65.6	65.3	64.9	64.5	64.1	63.7	63.4	63.0	62.6
1.00	62.3	61.9	61.5	61.1	60.7	60.4	60.0	59.6	59.2	58.8
1.10	58.5	58.1	57.7	57.3	57.0	56.6	56.2	55.8	55.4	55.1
1.20	54.7	54.3	54.0	53.6	53.2	52.8	52.4	52.1	51.7	51.3
1.30	50.9	50.6	50.2	49.8	49.4	49.1	48.7	48.3	47.9	47.5
1.40	47.2	46.8	46.4	46.0	45.7	45.3	44.9	44.5	44.1	43.8
etc.										

1/ Values in left column and top row are bulk density of sample. Tabulated values are porosity, calculated as follows:

$$\text{Percent porosity} = 100 - \left(\frac{\text{bulk density} \times 100}{2.65}\right)$$

Example: If sample has a bulk density of 1.13, the total porosity of the sample is 57.3 percent.

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